Safety and Earthing Design

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Types of Safety

There are two types of safety we must be familiar with when performing RBS installation verification processes:

1) **Personal Health and Safety**
2) **System Safety**

Personal Health and Safety: Admonitions

Personal health and safety admonitions are used to indicate hazardous activities and are normally preceded by the common hazard symbol (bottom right), or in specific cases by specialized symbols (next slide).

The hazard symbol is common for all three admonition levels. The three admonition levels are defined as:

Danger! Indicates that there is an imminent hazard that is likely to result in death or serious injury.

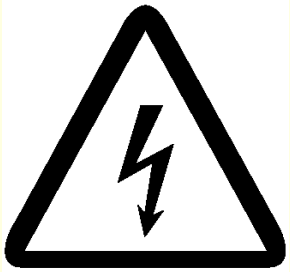
Warning! Indicates that there is a potential hazard that could result in death or injury.

Caution! Indicates a hazard that could result in minor or moderate injury.

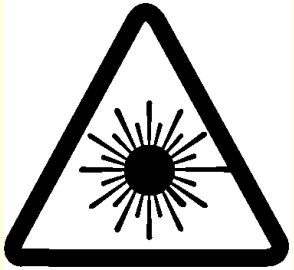
Personal Health and Safety: Special Hazard Symbols

Chemical Hazard

Heat Hazard



Electrical Hazard



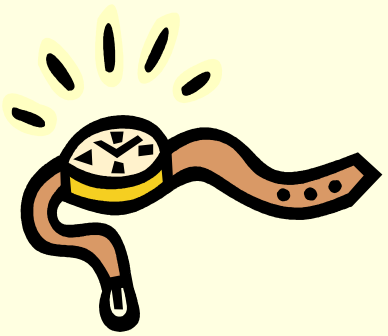
Laser Hazard

Fire Hazard

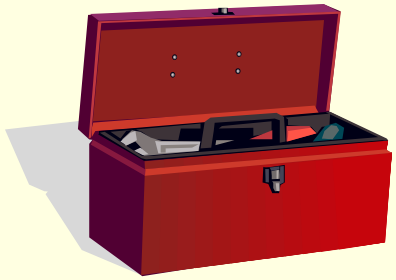
RF Exposure Hazard

Personal Health and Safety: General Safety Precautions

To ensure that persons are not injured when working with equipment:



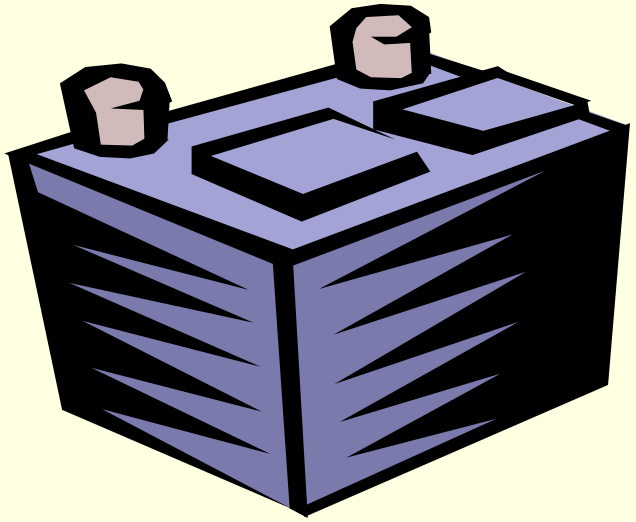
- Items of jewelry, for example rings, watches and necklaces should be removed as they can catch on moving parts, or when lifting equipment.
- Pay attention to the hazard labels and other information labels on products.
- Never remove or cover hazard symbols as this can endanger persons working with the product.
- Only use the tools described, and in the manner indicated, in the instructions



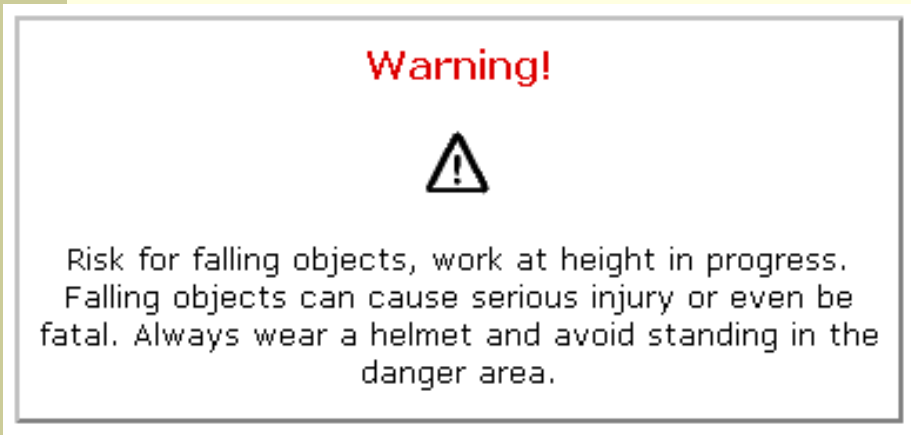
Personal Health and Safety: Avoiding Energy Hazards

The following precautions must be observed when working with batteries and other units that present an energy hazard:

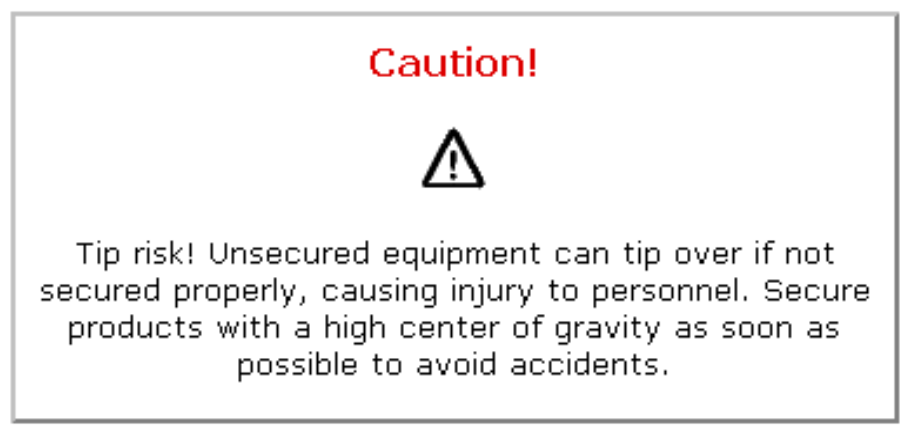
- All metallic objects worn, such as wrist watches, rings, bracelets, and so on are removed.
- Disconnect the charger power supply until the work is complete.
- Only use insulated tools.



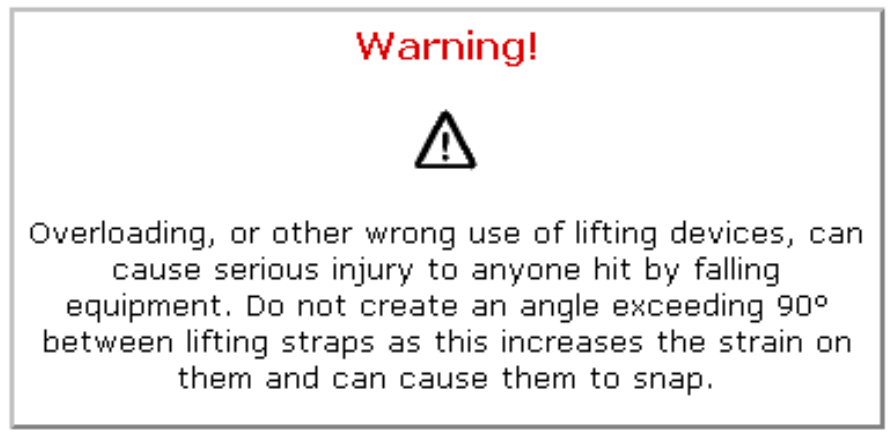
Personal Health and Safety: Handling Heavy Goods

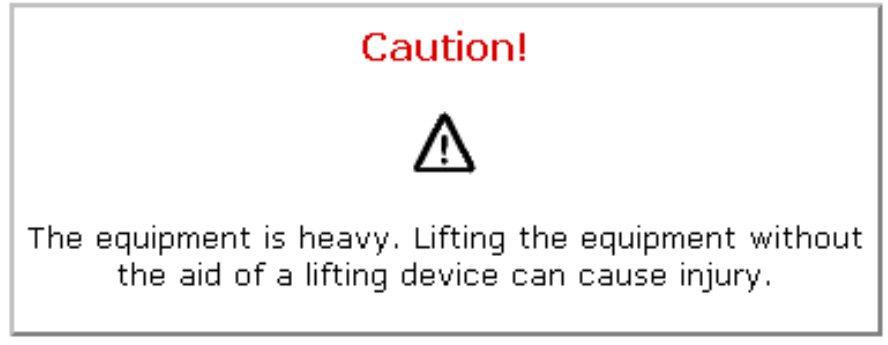

Warning!
Risk for falling objects, work at height in progress. Falling objects can cause serious injury or even be fatal. Always wear a helmet and avoid standing in the danger area.

Falling Objects


Caution!
Tip risk! Unsecured equipment can tip over if not secured properly, causing injury to personnel. Secure products with a high center of gravity as soon as possible to avoid accidents.

Unsecured Equipment


Warning!
Overloading, or other wrong use of lifting devices, can cause serious injury to anyone hit by falling equipment. Do not create an angle exceeding 90° between lifting straps as this increases the strain on them and can cause them to snap.

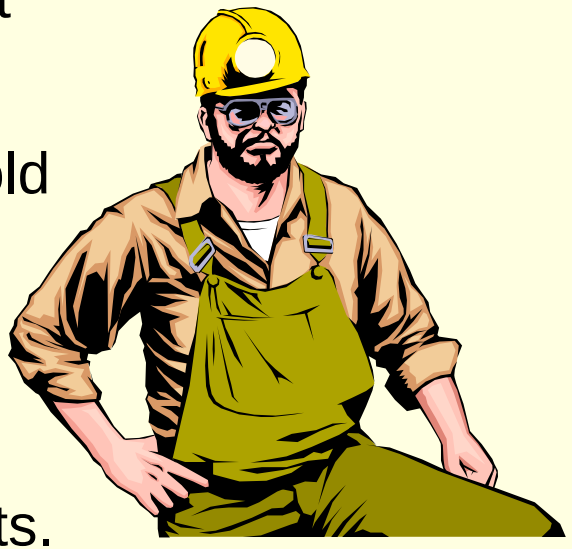


Overloading

Personal Health and Safety: Working at Heights

The following precautions must be observed when working at heights:

- Personnel have the appropriate training and medical certificate.
- A full-body safety harness and safety helmet are available.



- Adequate protective clothing, essential in cold and wet weather, is available.
- All lifting devices are tested, approved, and ready for use.
- All personnel in the area are wearing helmets.
- Take into consideration the local regulations.

System Safety: Product Safety Admonitions

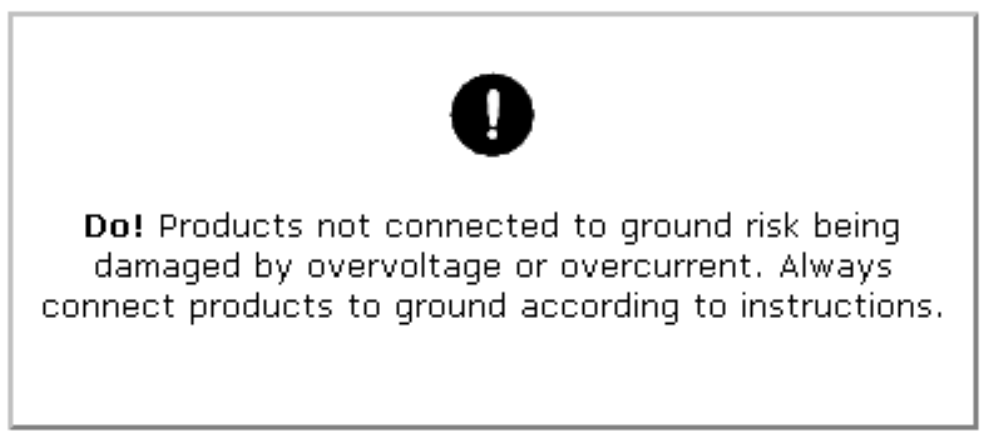
Do!
Safety Symbol

Indicates an action that must be performed to prevent equipment damage, software corruption, data loss or service interruption.

Stop!
Safety Symbol

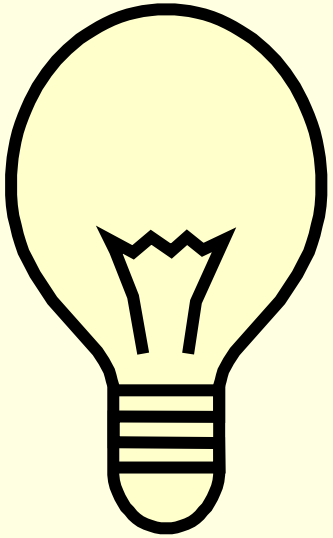
Indicates an action that must be avoided to protect equipment, software, data or service.

For example:


Do! Products not connected to ground risk being damaged by overvoltage or overcurrent. Always connect products to ground according to instructions.

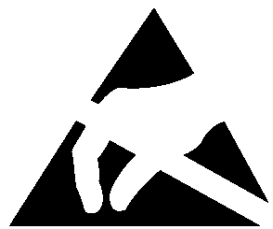
System Safety: Electrical Installation

The following precautions must be observed when working with electrical installations:



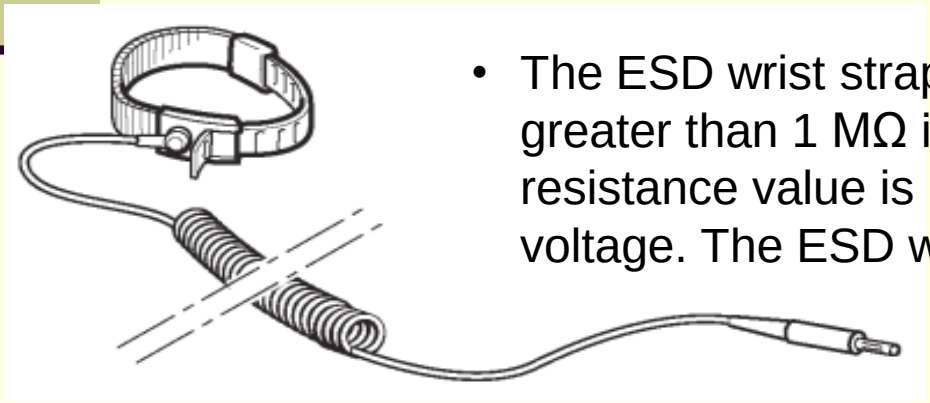
- Ensure that approved circuit breakers or fuses are installed.
- Ensure that the cables used have a sufficient cross-sectional area in accordance with product requirements and local laws and regulations.
- Ensure that conductors are connected according to the connection diagram.
- Label the cables correctly.
- Check the installation work upon completion.

System Safety: Electrostatic Discharge (ESD)



ESD Hazard Symbol

- A static electric charge accumulates when a body rubs against clothes, slides against a chair, when shoes rub against a floor, or when ordinary plastics are handled, and so on.
- The electrostatic charge can remain for a considerable length of time and is discharged when the body comes into contact with conductive material.
- An ESD wrist strap (below) must be used when working with ESD sensitive components, even in equipment rooms fitted with ESD protective floor covering.



- The ESD wrist strap contains a resistor with resistance greater than 1 MΩ in the cable to protect the operator. The resistance value is low enough to discharge the electrostatic voltage. The ESD wrist strap must be connected to ground.

Tool Set

WHAT IS EARTHING/GROUNDING ?

"Earthing/ Grounding" may be described as a system of electrical connections to the general mass of earth.

The Purpose of grounding

- to provide direct path for the fault currents to the soil and,
- while maintaining the step and touch voltages at acceptable values

Requirement of a good earthing system:

- Protection of buildings and installations against lightning
- Safety of human and animal life by limiting touch and step voltages to safe values
- Electromagnetic compatibility (EMC) i.e. limitation of electromagnetic disturbances
- Correct operation of the electricity supply network and to ensure good power quality.

The Standards

- **IEEE 80** Guide for Safety in AC Substation Grounding
- **IEEE 81** Guide for Measuring Ground Resistance an Potential Gradients in the Earth
- **IEEE 142** Recommended Practices for Grounding of Industrial and Commercial Power Systems
- **IEEE 1100** Recommended Practice for Powering and Grounding Electronic Equipment
- **BS 7430** Code of practice for Earthing.
- **IEC 60364-5-54** Electrical installations of buildings - Selection and erection of electrical equipment - Earthing arrangements

Definitions/Terminology

Earth/ ground	The conductive mass of the earth, whose electric potential at any point is conventionally taken as equal to zero.
Earth electrode	A conductive part or a group of conductive parts in intimate contact with and providing an electrical connection to earth.
Earthing network	The part of an earthing installation that is restricted to the earth electrodes and their interconnections.
Main earthing terminal	A terminal or bar that is provided for the connection of protective conductors, including equipotential bonding conductors and conductors for functional earthing, if any, to the means of earthing.
Earthing conductor	A protective conductor that connects the main earthing terminal or bar to the earth electrode.

Definitions/Terminology cont..

Equipotential bonding	Electrical connection putting various exposed conductive parts and extraneous conductive parts at a substantially equal potential.
Equipotential bonding conductor	A protective conductor for ensuring equipotential bonding.
Protective conductor (PE)	A conductor that is required by some measures for protection against electric shock by electrically connecting any of the following parts: •Exposed conductive parts •Extraneous conductive parts •Main earthing terminal •Earth electrode •Earthed point of the s

Definitions/Terminology cont..

Ground Resistance	The ohmic resistance between the grounding electrode and remote grounding electrode of zero resistance
Potential Profile	A plot of potential as a function of distance along a specified path.
Surface Potential Gradient	The slope of the potential profile, the path of which intersect equipotential lines at right angle
Ground Potential Rise (GPR)	The max. electrical potential that a grounding grid may attain relative to a distant grounding point assumed to be at potential of remote earth

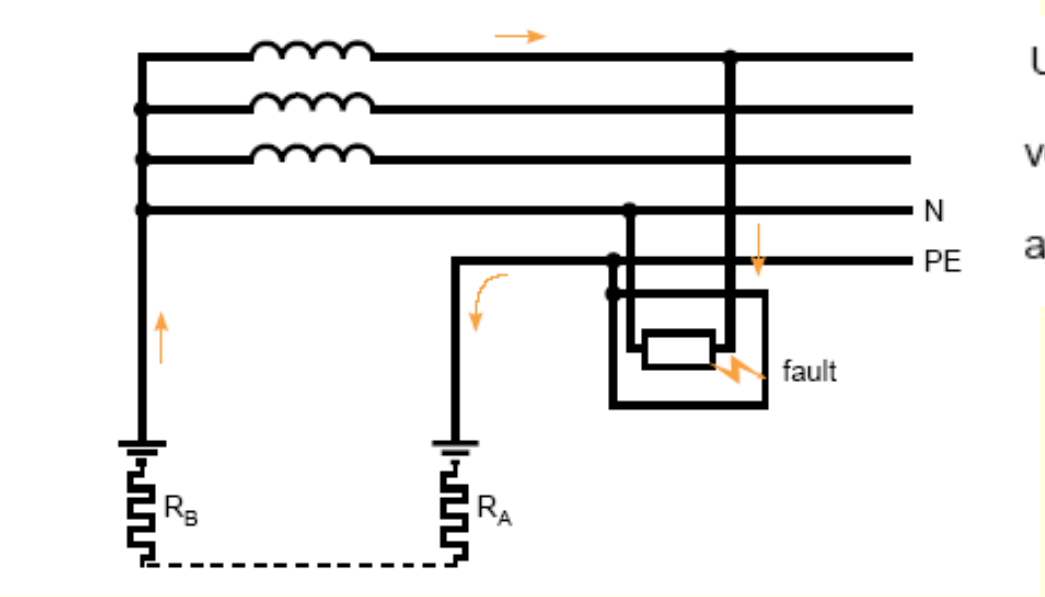
Types of Earthing Systems for Installations

- Earthing Systems according to IEC 364
  - TT
  - TN
  - IT

- These three earthing systems have been internationally standardised and currently taken over in many national standards.

Brief in Earthing Systems

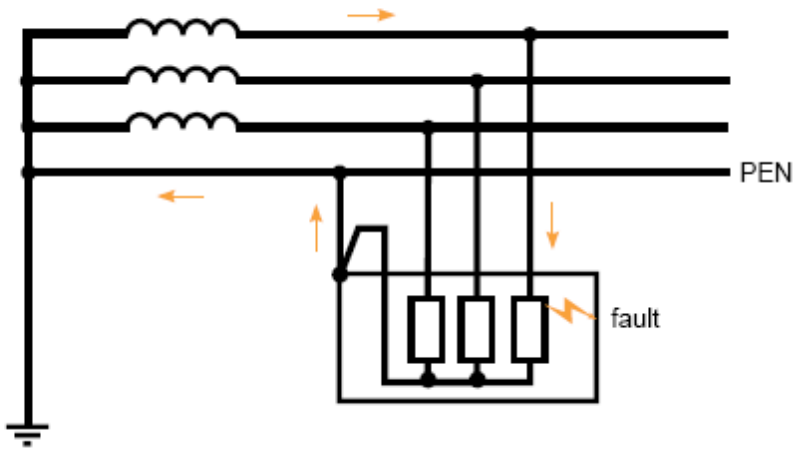
- TT
  - the transformer neutral is earthed;
  - the frames of the electrical loads are also connected to an earth connection.



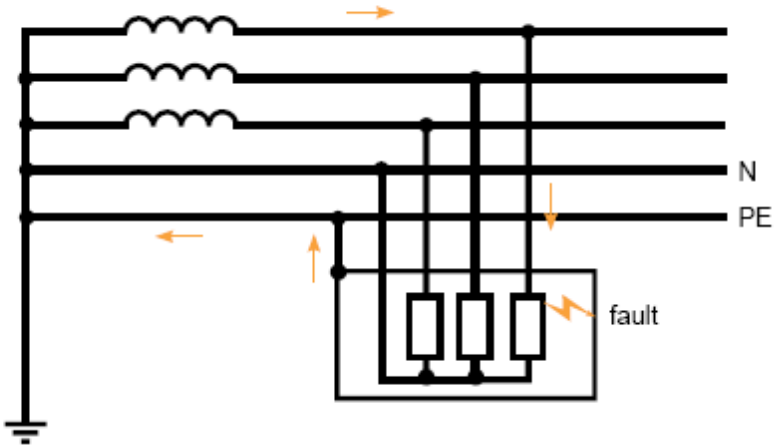
$$Uc = Uo \frac{R_A}{R_B + R_A}$$ greater than voltage U_L, the RCD comes into action as soon as $Id \geq \frac{U_L}{R_A}$.

TN Systems

TN-C system



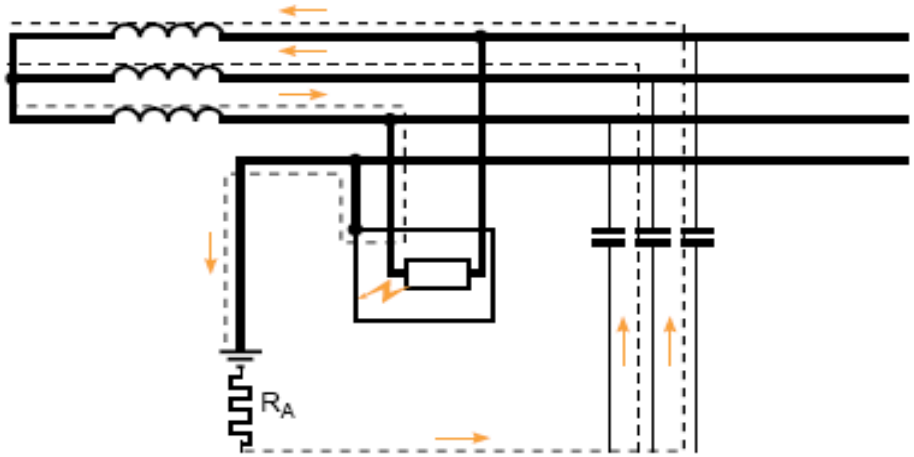
TN-S system



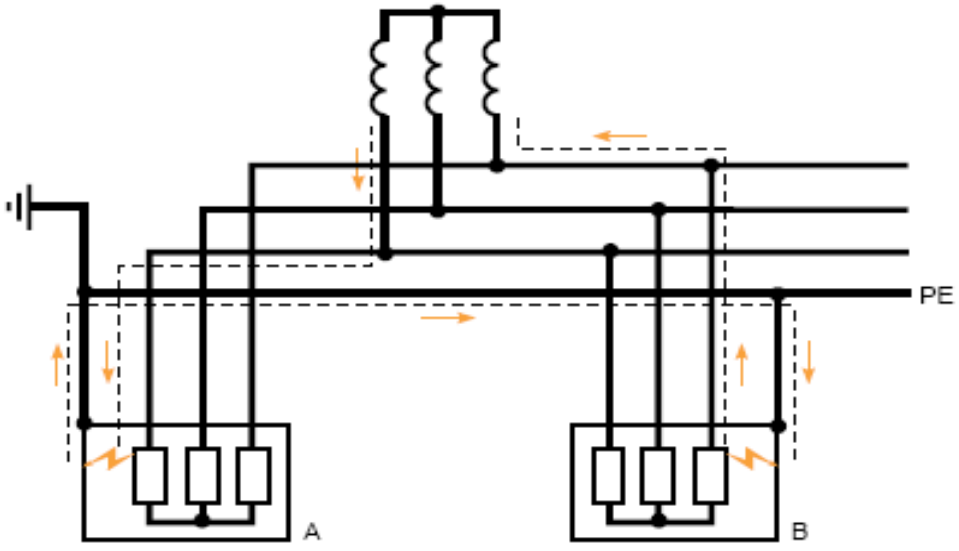
- Very High earth fault current
- Fault current depends on loop impedance
- Size of protective conductor depends on magnitude of fault current
-

IT System

1st fault



double insulation fault



Breaking Conditions

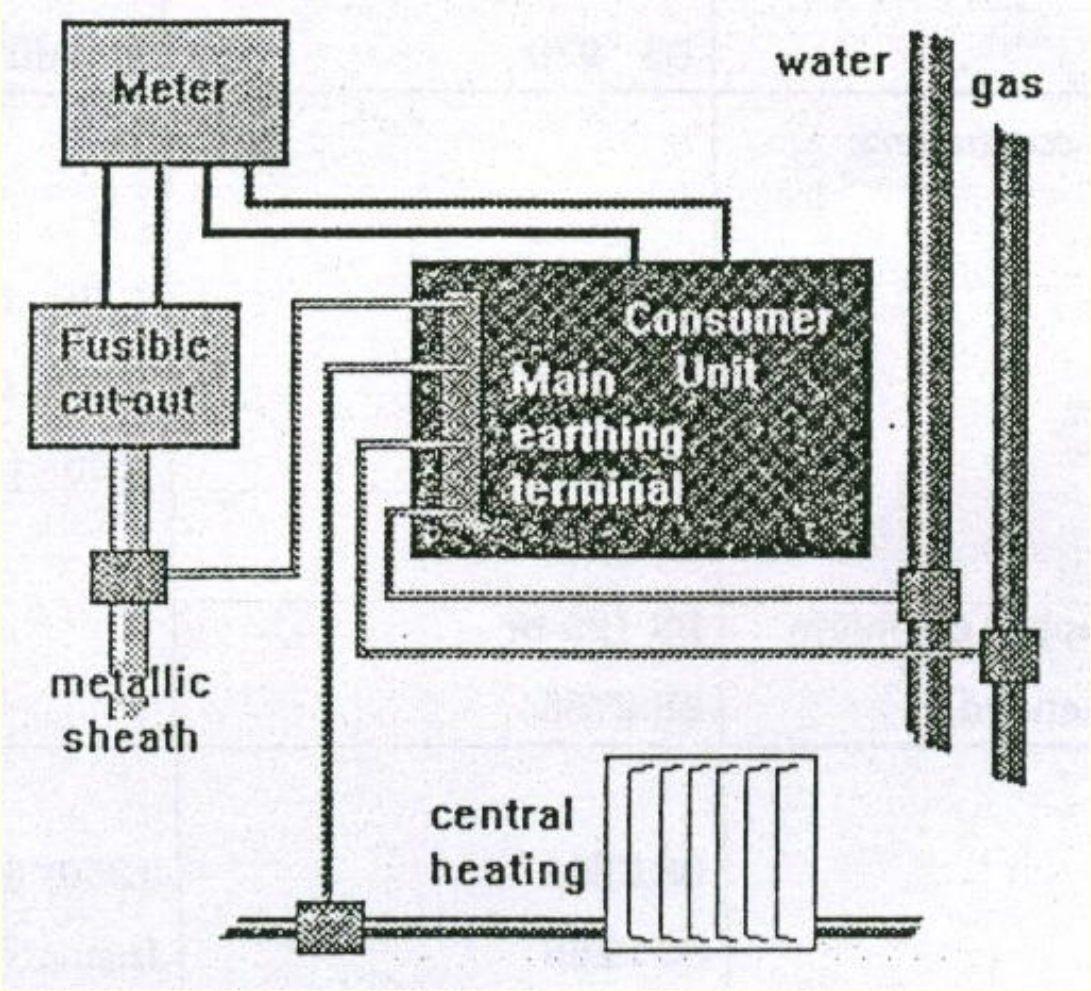
System	Protective Device	Breaking Condition
TT	Residual Current Insulation Monitoring Over Current	$R_A.I_a \leq 50V$
TN-C	Over Current	$Z_s.I_a \leq U_o$
TN-S	Residual Current Over Current	$Z_s.I_a \leq U_o$
TN-C-S	Residual Current Over Current	$Z_s.I_a \leq U_o$
IT	Residual Current Insulation Monitoring Over Current	$R_A.I_d \leq 50V$

R_A=Earth Resistance, Z_s= Earth loop impedance,

I_a= Operating current of Device, I_d= Fault current,

U_o= Rated Voltage against earth

Sizing of Earthing Conductors



Adiabatic Equation

- Adiabatic: Process take place without heat entering and leaving the system. (Close System)
- During a fault condition, it is assumed that the energy produced goes as heat and none is lost to atmosphere.
- Cross-Section area $A = \frac{\sqrt{I^2 t}}{k} \quad \text{mm}^2$
- It MCBs are used as protective device $A = \frac{\sqrt{a^2 I^2 t}}{k} \quad \text{mm}^2$

  a= 4 for Type 1
  7 for Type 2
  10 for type 3
  50 for type 4

Values for K

A9 Table 54 B of I E E Regulations

Values of k for insulated protective conductor not incorporated in a cable and not bunched with cables, or for separate bare protective conductor in contact with cable covering but not bunched with cables, where the assumed initial temperature is 30°C

Material of conductor	Insulation of protective conductor or cable covering			
	70°C p.v.c.	85°C p.v.c.	85°C rubber	90°C thermosetting
Copper	143/133*	143/133*	166	176
Aluminium	95/88*	95/88*	110	116
Steel	52	52	60	64
Assumed initial temperature	30°C	30°C	30°C	30°C
Final temperature	160°C/140°C*	160°C/140°C*	220°C	250°C

* Above 300 mm^2

A10 Table 54 C of I E E Regulations

Values of k for protective conductor incorporated in a cable or bunched with cables, where the assumed initial temperature is 70°C or greater.

Material of conductor	Insulation Material			
	70°C p.v.c.	85°C p.v.c.	85°C rubber	90°C thermosetting
Copper	115/103*	104/90*	134	143
Aluminium	76/68*	69/60*	89	94
Assumed initial temperature	70°C	85°C	85°C	90°C
Final temperature	160°C/140°C*	160°C/140°C*	220°C	250°C

* Above 300 mm^2

Properties of Earthing System

- The electrical properties of earthing system depend essentially on two parameters:
  - earthing resistance
  - configuration of the earth electrode.

- The earthing resistance has two components:
  - dissipation resistance R_D,
    (the resistance of the earth between the earth electrode and the reference earth)
  - resistance R_L of the metal parts of the earth electrode and of the earthing conductor.

- Normally $R_L << R_D$
- Thus, usually the **earthing resistance = the dissipation resistance R_D**

Earthing Systems

1. System earth,
2. Static earth,
3. Maintenance earth,
4. Equipment earth,
5. Electronic earth,
6. Lightning Protection earth.

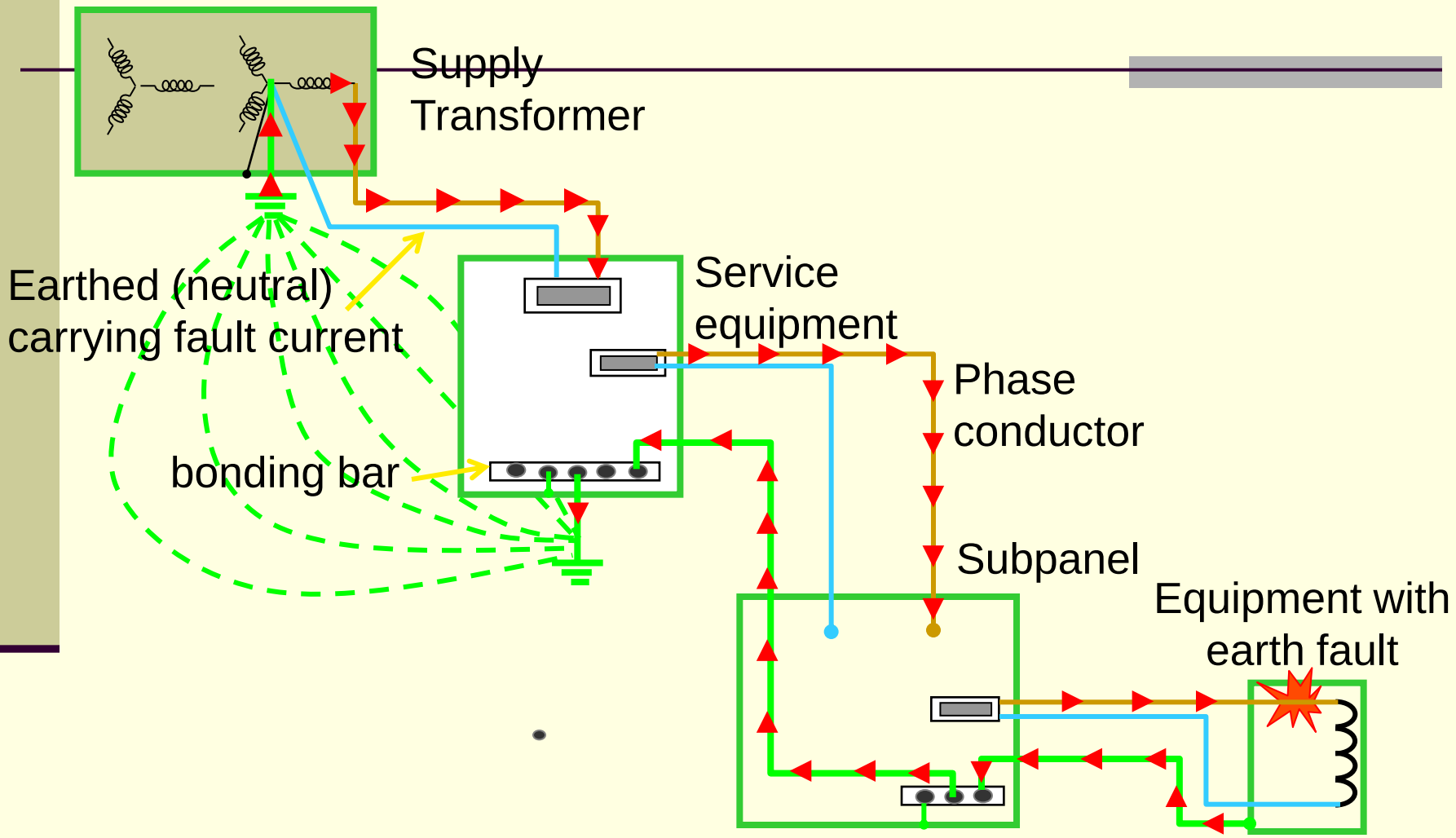
System Earth

- Refers to the point in an electrical circuit that is connected to earth.
  - typically at the electrical neutral
  - provides a low impedance path for fault currents improving ground fault coordination
  - ensures longer insulation life of motors, transformers and other system components.
- Intended to carry low frequency or fault currents back to protective devices.
  - primarily a current consideration

Circuit and system grounding

1. There are three fundamental purposes for grounding an electrical system:
2. To limit excessive voltage from lightning, line surges, and crossovers with higher voltage lines.
3. To keep conductor enclosures and noncurrent-carrying metal enclosures and equipment at zero potential to ground.
4. To facilitate the opening of overcurrent protection devices in case of insulation failures because of faults, short circuits, etc.

Grounding of electrical systems.

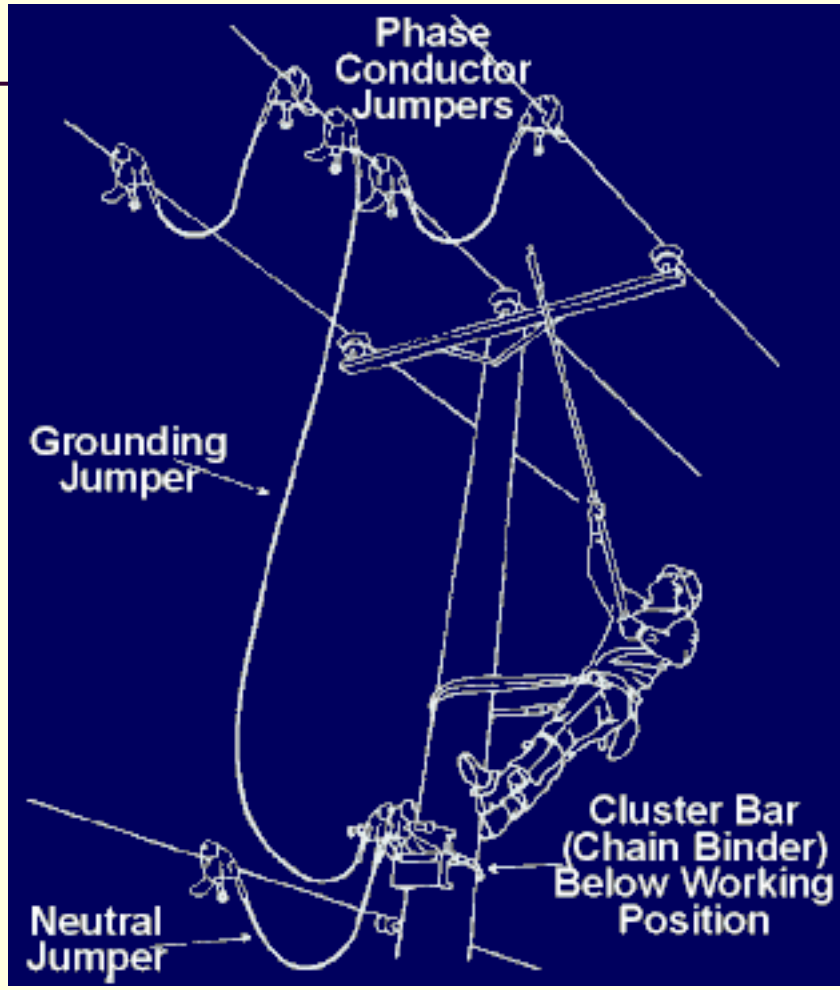


Static Earth

- Connection made between a piece of equipment and earth for the purpose of draining off static electricity charges
  - prevents flash over potential being reached.
  - utilized in dry materials handling, flammable liquid pumps and delivery equipment, plastic piping, and explosive storage facilities.

Maintenance Earth

- Utilized for safe work practices, and is a temporary earth.
- Equipotential personal grounding consists of one set of jumpers connecting all phases together and to both the neutral and a cluster bar mounted below the worker's feet.



Equipment Earth

Primarily a voltage consideration

Interconnected network of equipment grounding conductors to

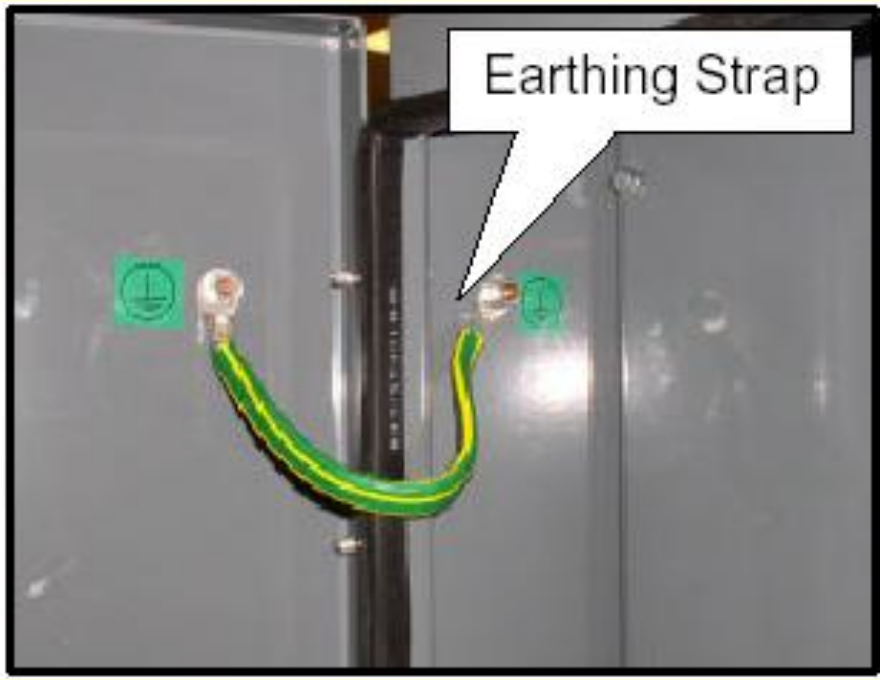
- Limit the hazard to personnel (shock voltage) from the exposed conducting parts of equipment, raceways etc
- Safely conduct ground-fault current at sufficient magnitude for fast operation of the circuit overcurrent protection devices.

Typical equipment to be grounded are electrical motor frames, outlet boxes, breaker panels, metal conduit, cable trays etc

Bonding to earth prevents potential rise which may shock an individual or flash over and cause a fire

Door Earth-Bonding Strap

- Door-earthing strap is attached to door and cabinet body by a 6mm earth strap.
- It is essential that these fixings remain in place and are regularly inspected to ensure an effective earth bond between the door and the main body of the cabinet.



Electronic and Computer Earth

- Earthing for electronic equipment is a special case in which the equipment earth and the system earth are combined.
- Electronic equipment earthing systems must not only provide a means of stabilizing input voltage levels, but also act as the zero voltage reference point.
- Earthing systems for modern electronics installation must be able to provide effective earthing and bonding functions well into the high frequency (MHz) range.

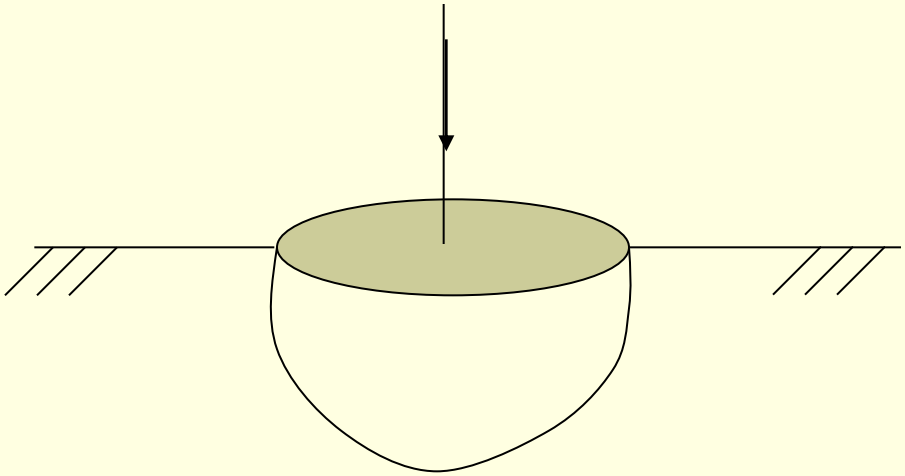
Lightning Protection Earth

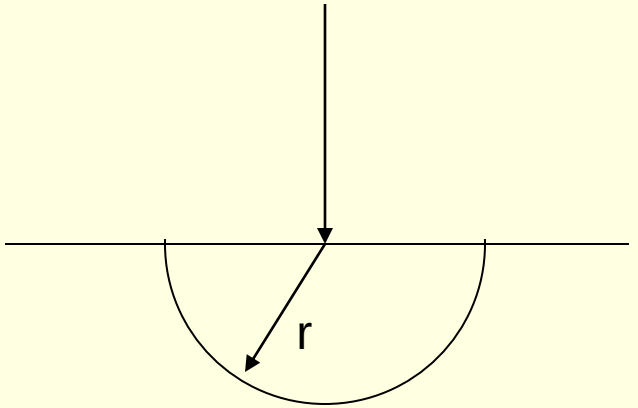
- Earthing requirements are dependent upon the structure, equipment to be protected, and the level of lightning protection required.
- Intended to provide a path to dissipate high energy into the soil.
- Primarily an energy consideration and may be accomplished by having an equal potential grid under the area to be protected.

Configuration of Earth Electrodes

- Hemi-Sphere Type
- Plate Type
- Rod Type
- Slip or conductor Type

Hemi-Sphere Type Electrodes

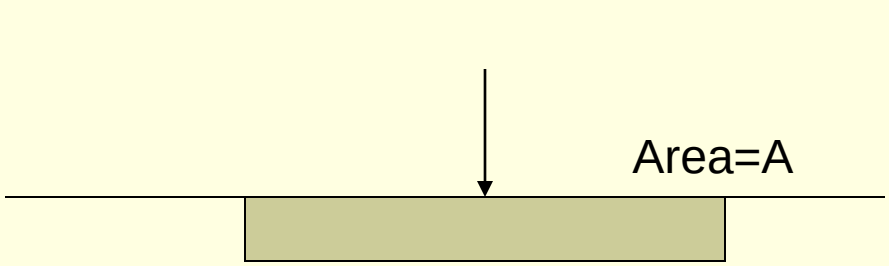


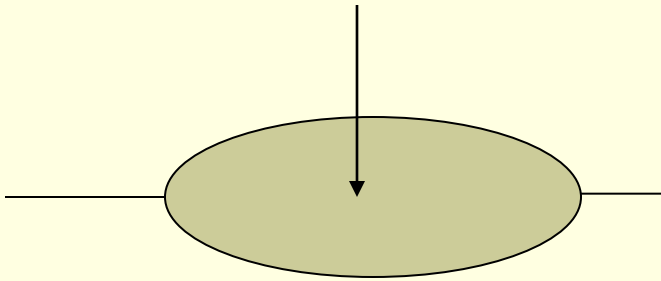


$$R_e = \frac{\rho}{2\pi r}$$

Plate Type Electrodes

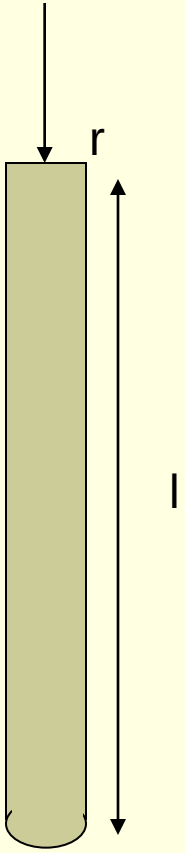
- Circular Plate





$$R_e = \frac{\rho}{4}\sqrt{\left(\frac{\pi}{A}\right)}$$

Rod/ Pipe Type Electrodes

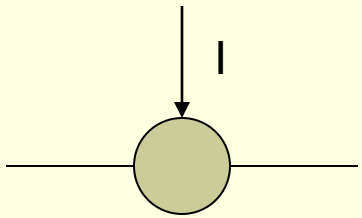


$$R_e = \frac{\rho}{2\pi l} \ln\left(\frac{l}{r}\right)$$

or

$$R_e = \frac{\rho}{2\pi l} \ln\left(\frac{2l}{r} - 1\right)$$

Slip or Conductor Type Electrodes



For earth conductors

$$R_e = \frac{\rho}{\pi l} \ln\left(\frac{l + 2r}{2r}\right)$$

For earth tape with width μ

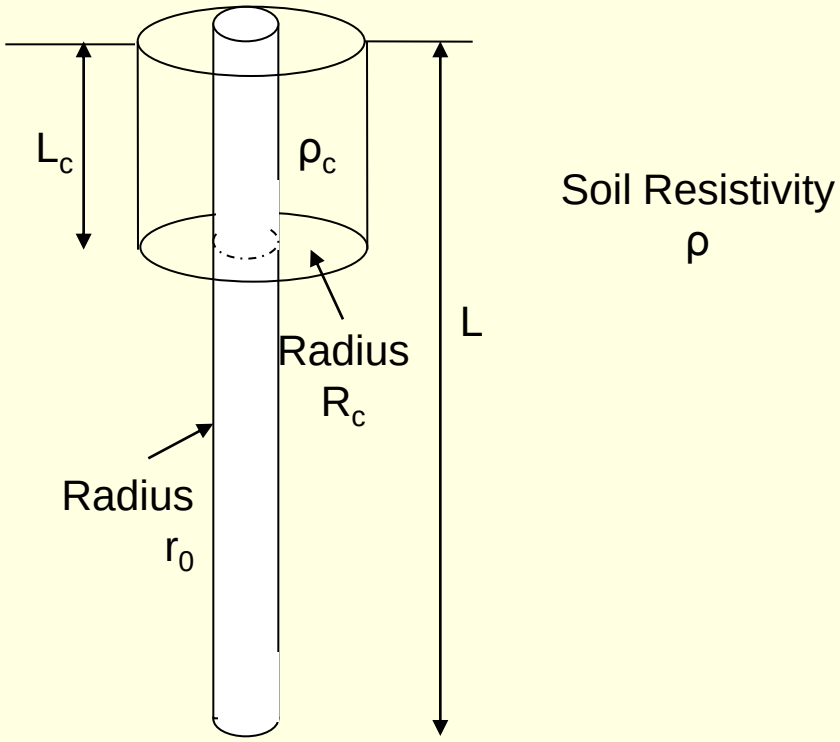
$$R_e = \frac{\rho}{\pi l} \ln\left(\frac{l}{\mu}\right)$$

Tape Barried at t depth

$$R_e = \frac{\rho}{2\pi l} \ln\left(\frac{2l^2}{\mu t}\right)$$

Assignment 01

- Derive an equation for the earth electrode resistance of a rod type earth electrode partially covered by a cylindrical concrete block as shown in the Figure



Tool set

- Personal Tool set (LTT 601 135/1)

Tool set

- Personal Tool Kit, Light (LTT 601 156/1)

Tool set

- Torque wrench kit

Torque wrench kit, 0.4 - 4.0Nm

Torque wrench kit, 20 - 100Nm

Torque wrench kit, 5 - 25Nm

Tool set

- Hammer Drill Machine

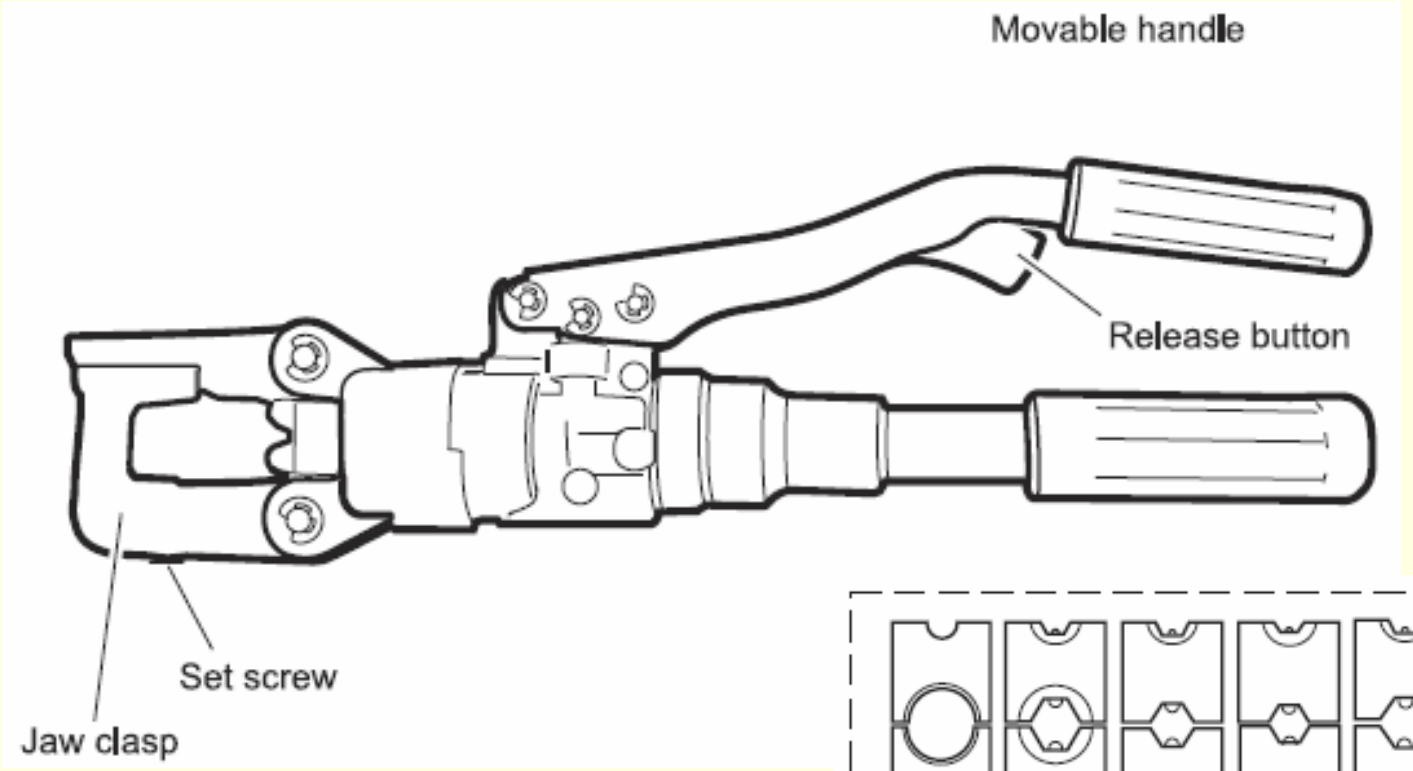
230 V

24 V (230 V charger)

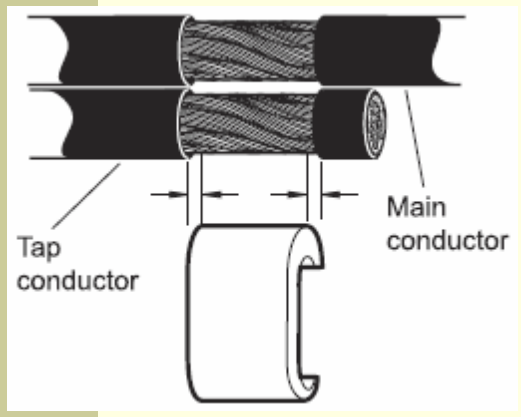
Earthing Tools sets

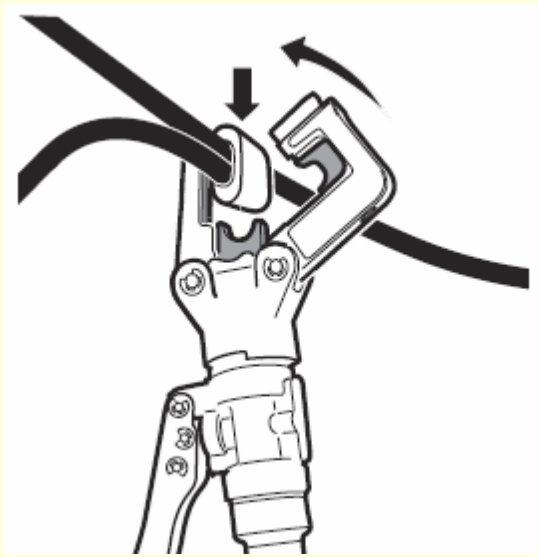
- **1) Hydraulic Crimping Tool set (LTT 601 86)**

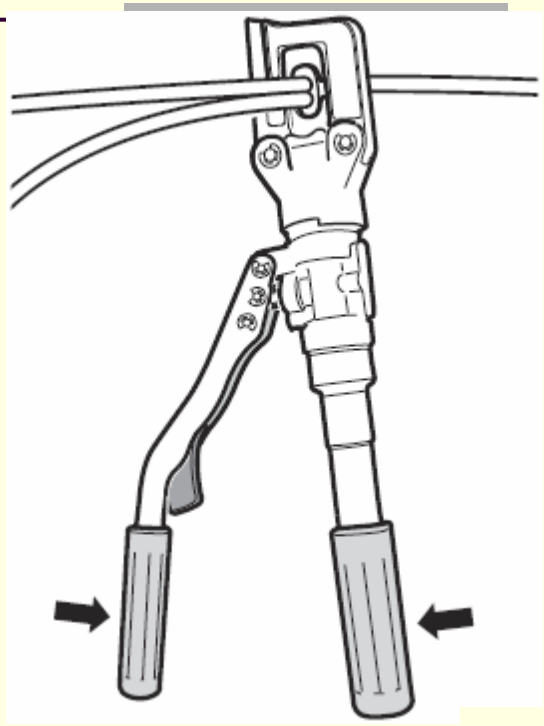
Crimping Tool LTT 601 86

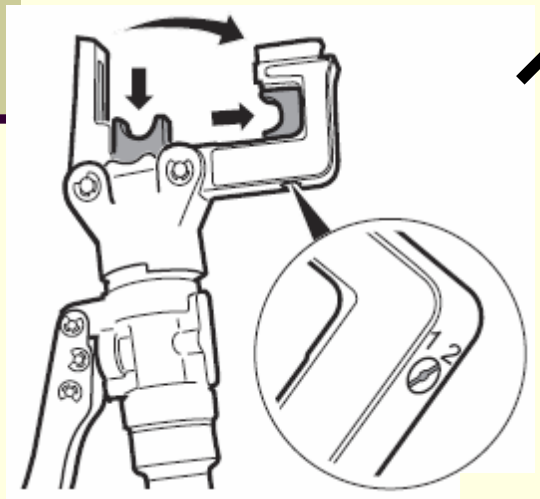


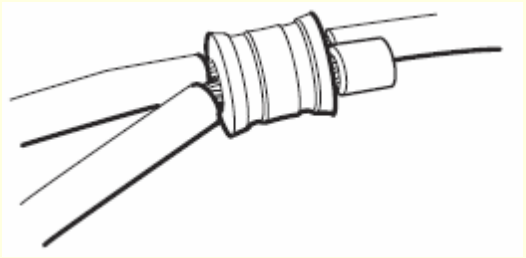
Crimping Tool





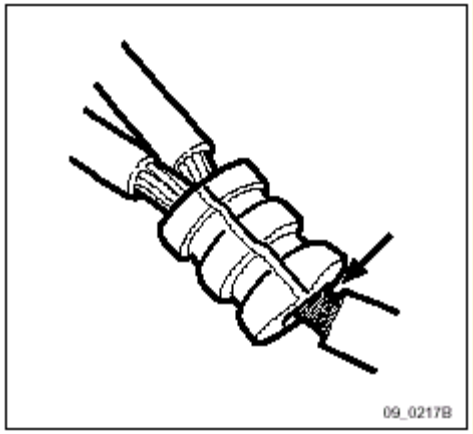


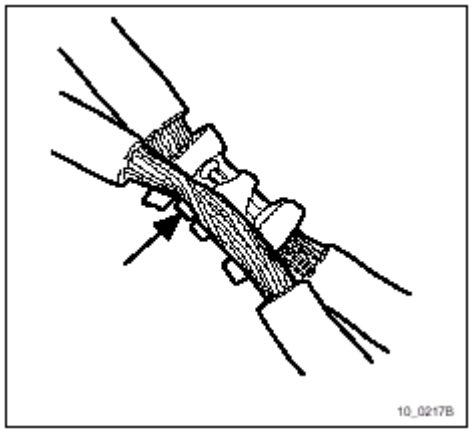




Crimping Tool Set Visual Inspection

Examples of faulty connections:





Visual Inspection:

a) The crimp is in the right place with full depth.

b) All wires in the conductors are undamaged and pressed together inside the crimped object.

c) The wires of the conductor have passed all the way through the C-clamp, or are visible through the inspection hole in the lug.

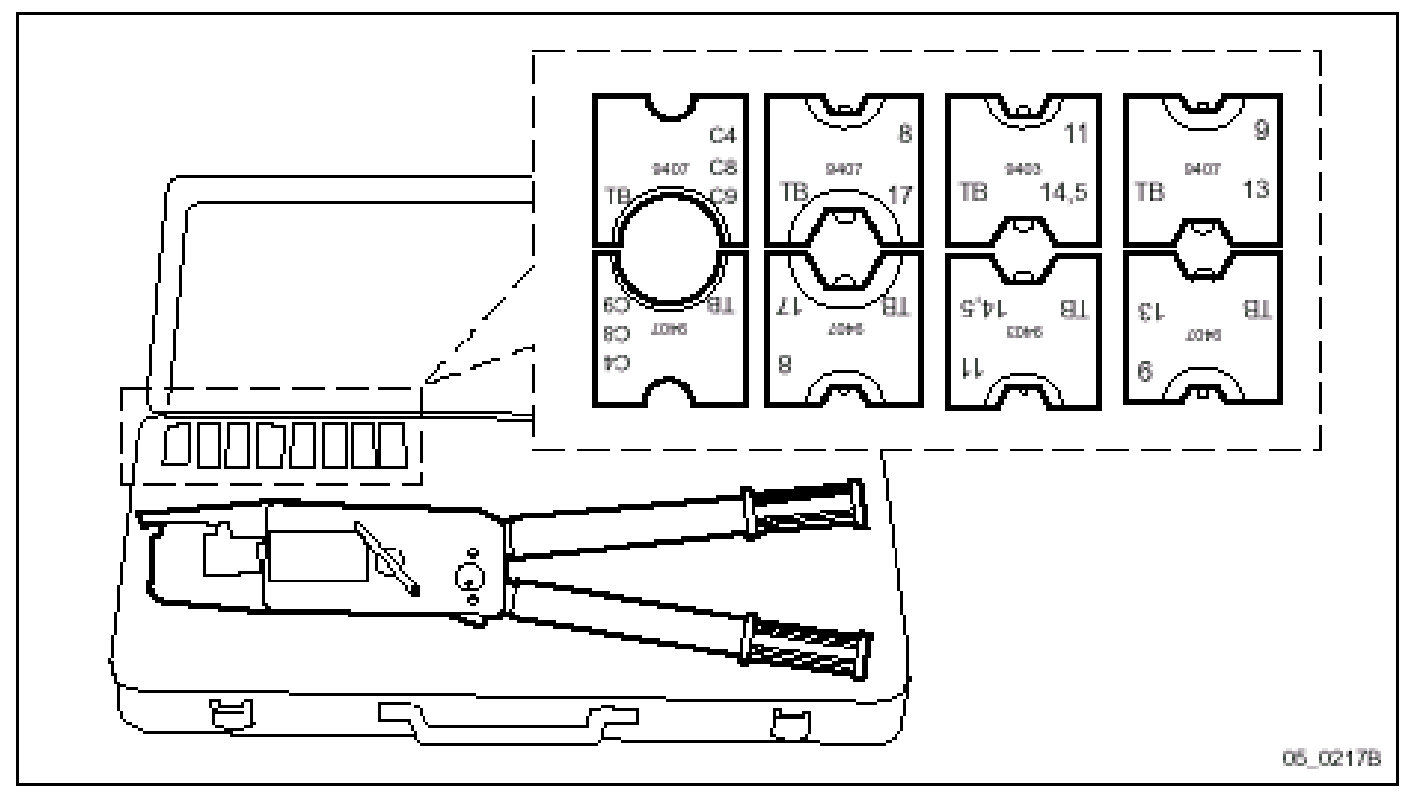
d) No visible cracks or other damage to crimping object or conductor.

e) 2 crimpings only if cable lug size is equal to or bigger than 70mm^2

Earthing Tools set

- **2) Mechanical/Manual Crimping Tools set (LTT 601 87)**

Crimping Tool LTT 601 87



Crimping Tool - LTT 601 87

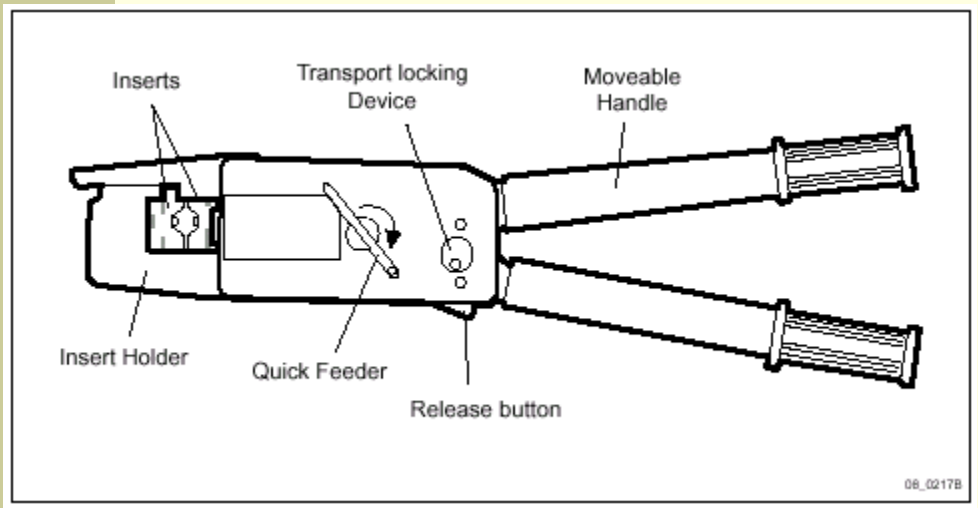


Table 2 Cable lugs

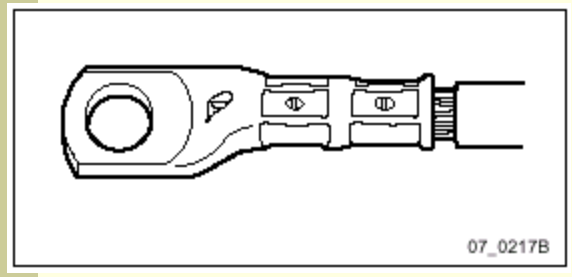
Die pair marked	Conductor area mm^2	Cable lug
8 17	10 70	8 17(1)
9 13	16 35	9 13
11 14.5	25 50	11 14.5

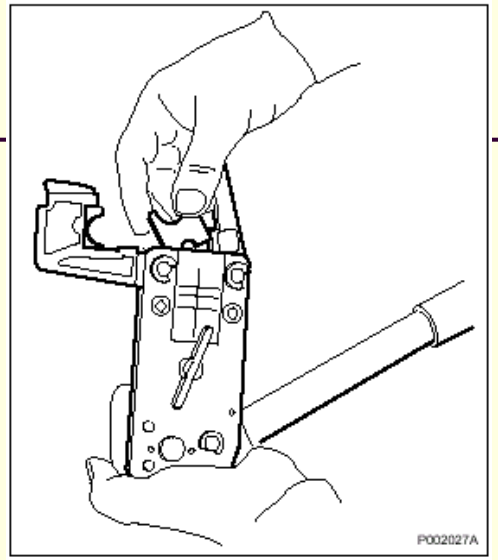
(1) Two crimpings shall be made side by side

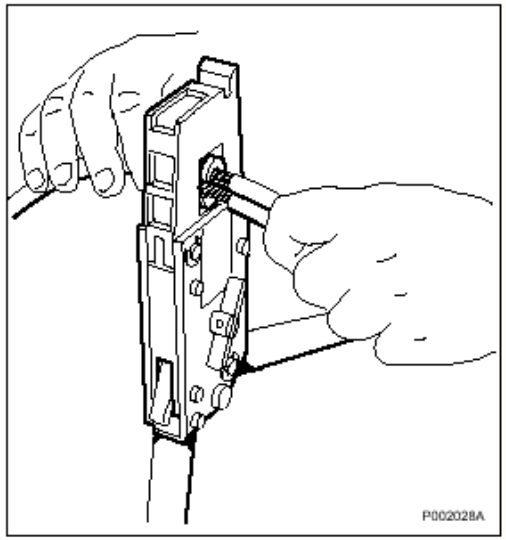
Table 3 Crimping objects: C-clamps

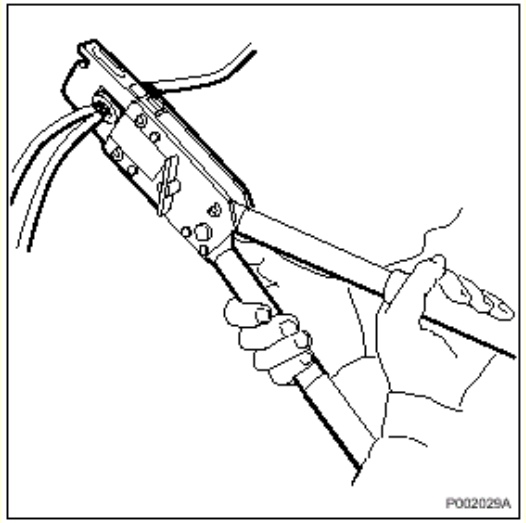
Wire 1 in mm^2	Wire 2 in mm^2	use C-clamp marked	use Tool LTT 601 86 with Die marked
25	25	C8-6	C8-C9
35	16	C8-6	C8-C9
35	25	C8	C8-C9
35	25	C9-6	C8-C9
35	35	C9-8	C8-C9
50	16	C9-6	C8-C9
50	25	C9-8	C8-C9
50	35	C9	C8-C9

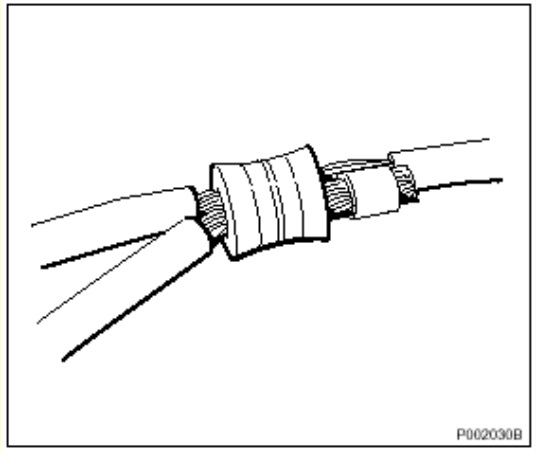
Crimping Tool LTT 601 87, User's Guide

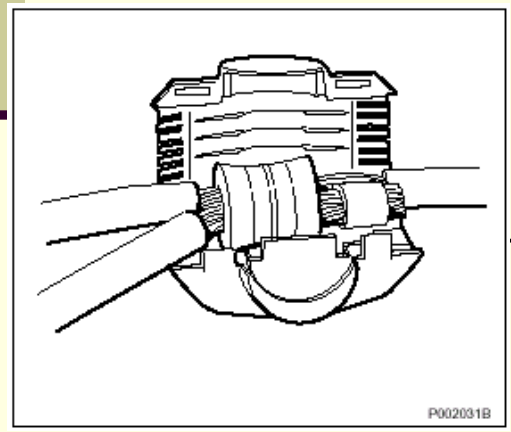






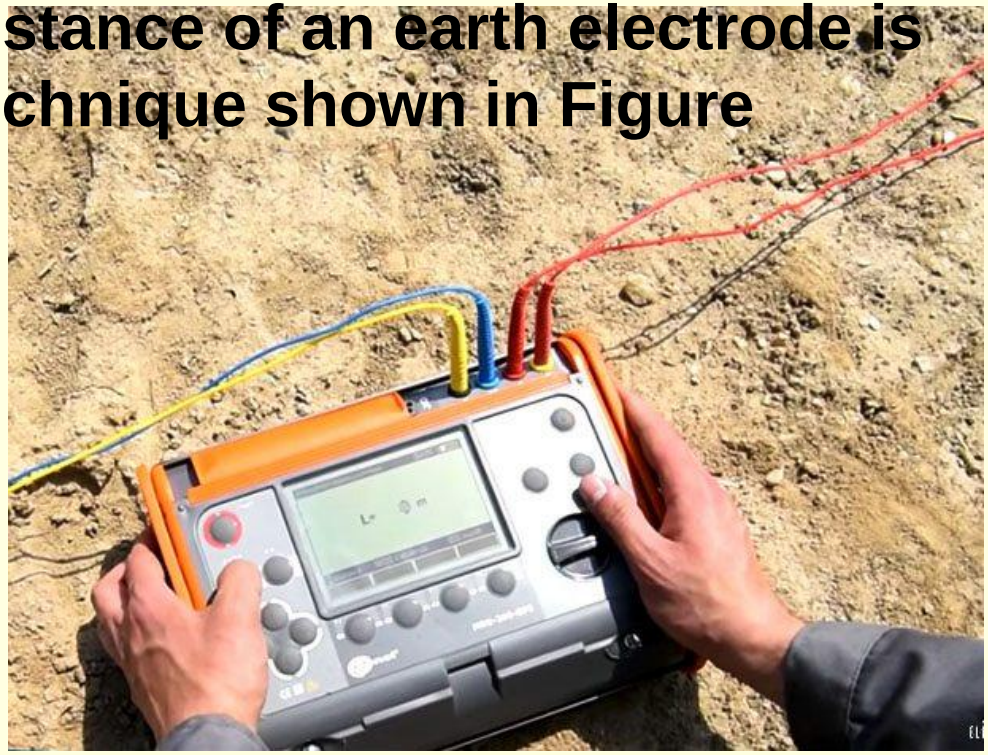






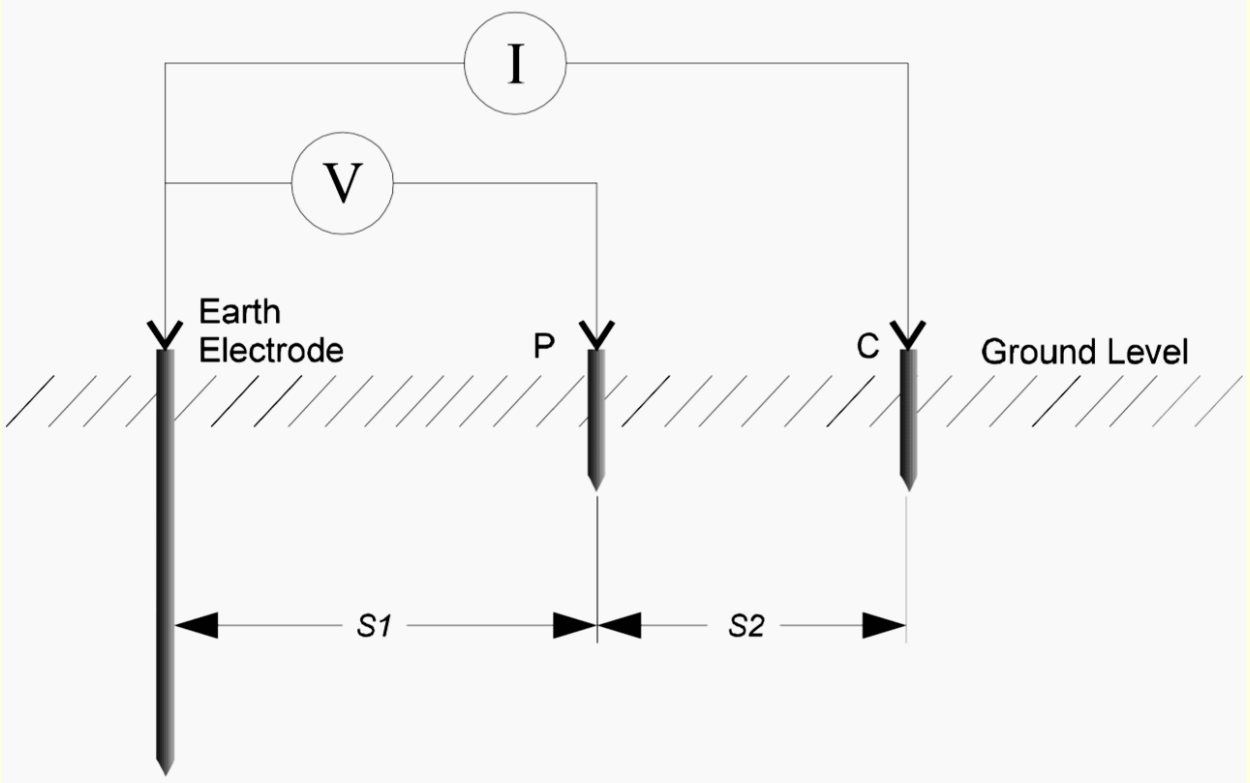
Earth resistance of an earth electrode

When an earth electrode system has been designed and installed, it is usually necessary to measure and confirm the earth resistance between the electrode and “true Earth”. The most commonly used method of measuring the earth resistance of an earth electrode is the 3-point measuring technique shown in Figure



This method is derived from the 4-point method, which is used for soil resistivity measurements

The 3-point method, called the **“fall of potential” method**, comprises the Earth Electrode to be measured and two other electrically independent test electrodes, usually labelled P (Potential) and C (Current). These test electrodes can be of lesser “quality” (higher earth resistance) but must be electrically independent of the electrode to be measured.



An alternating current (I) is passed through the outer electrode C and the voltage is measured, by means of an inner electrode P, at some intermediary point between them.

The Earth Resistance is simply calculated using Ohm's Law: **Rg = V/I.**

Other more complex methods, such as the Slope Method or the Four Pole Method, have been developed to overcome specific problems associated with this simpler procedure, mainly for measurements of the resistance of large earthing systems or at sites where space for locating the test electrodes is restricted.

Table – Variation of current and voltage electrode separation with maximum earth system dimensions, in meters

Maximum dimension across earth system	Distance from 'electrical centre' of earth system to voltage test stake	Minimum distance from 'electrical centre' of earth system to current test stake
1	15	30
2	20	40
5	30	60
10	43	85
20	60	120
50	100	200
100	140	280

The Fall of Potential method incorporates a check to ensure that the test electrodes are indeed positioned far enough away for a correct reading to be obtained. It is advisable that this check be carried, as it is really the only way of ensuring a correct result.

EARTH ROD & ELECTRODE BACKFILL

Bentonite that is a moisture retaining clay used as an earth electrode back-fill to help lower soil resistivity – the conductive Bentonite clay is a sodium activated montmorillonite which when mixed with water swells to several times its original volume mass when in a dry condition.

Bentonite is supplied in 20kg granular and powder forms.